University of Technology Sydney

The spread of the native macroalga *Caulerpa filiformis*

By

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student:

Date:

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Preface

This thesis consists of six chapters. Chapters 2 to 5 have been written as separate articles that have either been published, are in review or are in preparation for submission to peer reviewed scientific journals. These papers are included as or close to their published or submitted form, and as a result, some repetition occurs. To prevent unnecessary duplication, with the exception of Chapter 2, a single reference list has been provided at the end of this thesis.

Chapter 2 contributed to an article that has been published in *Marine and Freshwater Research* 66(11) 1018-1026 (2015). This article is inserted in the thesis in the same format as how it has been published. The rest of this work is in submission to *Marine and Environmental Research*.

The second study of this chapter, "Habitat associations of a range expanding native alga across its geographic range", has been submitted to *Marine Environmental Research*. Authors of this manuscript are Sofie Voerman, Tim Glasby, William Gladstone and Paul Gribben. S. Voerman conducted all the experimental work and analysis and wrote the manuscript, T. Glasby, W. Gladstone and P. Gribben provided conceptual advice and guidance. Chapters 3-5 are in preparation for submission to scientific journals. Author contributions are as described above. Chapter 2 received contribution from Sam Burrell, who helped with the laboratory work.

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Abstract

Marine coastal systems are threatened by a wide range of anthropogenic pressures. Of particular concern are increased sediment and nutrient runoff. Moreover, hotspots of anthropogenic pressures are also where invasive species tend to be. The spread of invaders can directly translate to a loss of biodiversity and associated ecosystem services. There is a growing awareness that the spread of native species can have similar large impacts on biodiversity and ecosystem function to their famous non-native counterpart. Yet the how, when and why a native species transitions to a 'native-invader' (*sensu* Simberloff and Rejmánek 2010) are poorly known. This is especially true in the marine environment. In New South Wales (NSW), eastern Australia, a native green macroalga from the notorious *Caulerpa* genus, *C. filiformis*, has spread both inside and outside its native range.

This study investigated the mechanisms that may have promoted the success of *C. filiformis*. The main aims were to increase our understanding on why this species has become so abundant, the habitat associations of the alga across large and local spatial scales, and the potential impacts on the seaweed community. In Chapter 2, large scale surveys showed that adult population abundance was related to sedimentation at multiple spatial scales, such as Reef Beach Index (RBI), reef width and the presence of a sediment veneer on top of the rocky reef (r+s habitat). In contrast, a low association with turf habitat was found, which is opposite to the observations for several other

Caulerpa invaders. A model was proposed where the adult association with r+s represents an end stage of succession after outcompeting turfing alga. Moreover, it was shown that the seaweed community showed reduced morpho-functional richness in presence of *C. filiformis*. To test the proposed model, habitat association of the recruitment stage was investigated in Chapter 3. Surveys at several locations throughout the alga's distribution showed that *C. filiformis'* recruit abundance was found to be high on turfing algae habitat and not on r+s habitat. This positive association of the recruitment stage was observed for coralline forms of turfing alga, but not for filamentous forms. Those results support the model hypothesized. Additionally, the mechanisms behind this positive association were further explored in this chapter. A laboratory experiment revealed that the high association of *C. filiformis*' recruits with coralline alga was explained by the increased attachment performance of *C. filiformis* fragments on this substrate. Namely, the increased structural complexity of coralline alga aided in rapid and strong attachment of fragments.

Finally, mechanisms that may benefit post-recruitment processes of *C. filiformis*, and in particular the role of turf habitat, were investigated. With the use of long term field observations in Chapter 5, it was shown that established *Caulerpa* appears a poor competitor, and possibly requires further disturbance to spread. For example, a laboratory experiment showed that *C. filiformis* is highly tolerant to large sedimentation rates, aided by rapid morphological plasticity (Chapter 4). This may benefit the alga indirectly if sediment more negatively affects competitors. Moreover, increased

sediment-nutrient availability was shown to promote growth rates, benefitting the alga's competitive strength (Chapter 5).

Overall, my thesis indicates that disturbance to native macrophytes indirectly promotes recruitment success by promoting turf habitat and that its continued spread is reliant on further disturbance to native communities – a model that has been demonstrated to invasive marine algae but not previously for a rapidly spreading native alga.